

# REPORT

## NON-INVASIVE GEOPHYSICAL SURVEYS DOUGLASS MEMORIAL AND PENNY HILL CEMETERIES ALEXANDRIA, VIRGINIA



Project No. 2191

December 2019

Prepared for:



Alexandria Archaeology  
Office of Historic Alexandria  
105 N. Union Street, #327  
Alexandria, VA 22314

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NON-INVASIVE GEOPHYSICAL SURVEYS  
DOUGLASS MEMORIAL (44AX0140) AND PENNY HILL  
(44AX0134) CEMETERIES  
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# TABLE OF CONTENTS

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	PAGE
LIST OF FIGURES .....	ii
ACRONYMS AND ABBREVIATIONS.....	ii
ABSTRACT.....	i
1.0 INTRODUCTION .....	1-1
2.0 HISTORICAL BACKGROUND .....	2-1
3.0 TECHNICAL BACKGROUND.....	3-1
3.1 Ground Penetrating Radar (GPR) .....	3-1
3.2 Soil Conductivity Measurements .....	3-2
3.3 Geomorphic/Geologic Background .....	3-3
4.0 FIELD PROCEDURES AND DATA PROCESSING .....	4-1
4.1 GPR Surveying .....	4-1
4.2 EM-38 Survey.....	4-3
5.0 INTERPRETATION AND RESULTS .....	5-1
5.1 Douglass Memorial Cemetery .....	5-1
5.1.1 EM-38 Results.....	5-1
5.1.2 GPR Results.....	5-2
5.2 Penny Hill Cemetery.....	5-4
5.3 Summary .....	5-7
6.0 ACKNOWLEDGEMENT.....	6-1
7.0 REFERENCES .....	7-1

## LIST OF FIGURES

---

FIGURE 1	Survey Locations
FIGURE 2	Douglass Memorial Cemetery Survey Area on Local Grid
FIGURE 3	Penny Hill Cemetery Survey Area on Local Grid
FIGURE 4	Surficial Geologic Setting
FIGURE 5	Ground Conductivity, All Values, Douglass Memorial Cemetery
FIGURE 6	Ground Conductivity, Typical Soil Range, Douglass Memorial Cemetery
FIGURE 7	Shallow Features, Not Obviously Grave Related, Douglass Memorial Cemetery

## LIST OF CHARTS

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CHART 1	Interpretive Map from Geophysical Survey, Douglass Memorial Cemetery
CHART 2	Interpretive Map from Geophysical Survey, Penny Hill Cemetery

## ACRONYMS AND ABBREVIATIONS

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EM	Electromagnetic
GPR	Ground Penetrating Radar
MHz	MegaHertz (million cycles per second)
mS/m	MilliSiemen per meter (unit of conductivity)
Rhea	Rhea Engineers & Consultants, Inc.

## ABSTRACT

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This report presents the results of non-invasive geophysical surveys, conducted in October 2019 at the Douglass Memorial and Penny Hill Cemeteries in Alexandria, Virginia by Rhea Engineers and Consultants, Inc. (Rhea) on behalf of Alexandria Archaeology. The scope of the investigation was to map the graves based on their geophysical signatures in these two sparsely documented historic cemeteries currently maintained by the City of Alexandria.

Two techniques were used for subsurface surveying. A Geonics EM-38 ground conductivity meter was used to map the variation of shallow electrical properties of the ground on the basis of electromagnetic (EM) measurements. Interference from Dominion's Jefferson Street Substation prevented conductivity surveying at Penny Hill Cemetery. Both cemeteries were surveyed with ground penetrating radar (GPR), using a MALÅ Geoscience system with a shielded 250 MHz antenna, which proved to be successful in delineating graves. Both cemeteries exhibit dense concentrations of graves.

At Douglass Memorial Cemetery, the estimated number of graves (in excess of about 780) is below the approximately 2,000 recorded burials, but more than can be inferred from the presence of headstones. In the western half of the cemetery, headstones generally correlate with strong subsurface anomalies, but there are also graves where headstones are absent. On the eastern side, gravestones are more standardized in form and distribution, but there is generally less correlation between grave locations and headstones.

In particularly dense areas at Penny Hill Cemetery, graves intersected one another, making it impossible to discern the boundaries of individual burials. The cemetery contains at least 2,075 graves, not accounting for the presence of overlapping or intersecting burials. This estimate represents the low-end of the range of possible grave counts for Penny Hill Cemetery.

In both cemeteries, the number of well-defined graves is low (close to about 10%). The lack of intact vaults or caskets likely reflects the socioeconomic limitations of the families of the interred. In a relatively more affluent cemetery, individual graves would appear more clearly in the GPR record. Accordingly, the identification of graves at these two sites required considerable interpretive effort. Ground truthing is the only definitive means to confirm the results of this survey.

## 1.0 INTRODUCTION

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This report presents the results of non-invasive geophysical surveys conducted at the Douglass Memorial and Penny Hill Cemeteries in Alexandria, Virginia (Figure 1) by Rhea Engineers and Consultants, Inc. (Rhea) of Valencia, PA with a branch office in Alexandria, VA on behalf of Alexandria Archaeology. The surveys were conducted from October 15 – 23, 2019 by William J. Johnson PG and Nadia E. Johnson RPA with support from Benjamin Skolnik, Ph.D. of Alexandria Archaeology. The scope of the investigation was to apply geophysical technology to evaluate the Douglass Memorial and Penny Hill Cemeteries, two sparsely documented historic cemeteries currently maintained by the City of Alexandria. Specifically, the surveys were designed to map the graves in these cemeteries based on their geophysical signatures.

The subsurface surveying was conducted using two techniques. A Geonics EM-38 ground conductivity meter was used to map the variation of shallow electrical properties of the ground on the basis of electromagnetic (EM) measurements. The two cemeteries were also surveyed using ground penetrating radar (GPR) using a MALÅ Geoscience system with a shielded 250 MHz antenna.

Subsequent sections of this report present the historical background of the two cemeteries (Section 2.0), as well as the technical background for GPR and measurements of ground conductivity with the EM-38 as applied to the mapping of graves (Section 3.0). Section 3.0 also provides the geologic/geomorphic background of the two cemeteries. The field procedures and data processing for both cemeteries are presented in Section 4.0. Section 5.0 discusses the interpretation of the data, and the appended maps present the detected graves with a classification of well-defined (probable intact coffin or vault), readily identifiable, but not as well-defined, and probable graves that are not readily interpretable. This latter category also covers areas where so many burials are concentrated in a single location that it is not practical to distinguish individual graves. Section 6.0 presents the acknowledgement that this work was conducted as a project funded by a Certified Local Government grant awarded to the City of Alexandria.

## 2.0 HISTORICAL BACKGROUND

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Douglass Memorial Cemetery (Figure 2) was established in 1895 as an African American cemetery and is now maintained by the City. The cemetery was in use until 1975. Douglass Memorial Cemetery (44AX0140) is located at 1421 Wilkes Street, in the northern section of the Wilkes Street cemetery complex. Douglass Memorial is named for Frederick Douglass, whose year of death coincides with the founding of the cemetery.

According to the City of Alexandria Parcel Viewer, the current parcel measures approximately 338 feet long and 184 feet wide and consists of 1.40 acres. Marked graves are present beyond the southern boundary of this parcel, and the cemetery extends into approximately 20 feet of the Wilkes Street right of way to include approximately 6,000 additional square feet. The cemetery was established in 1895 to serve Alexandria's African American community (Miller 1987b; Pippenger 1992b).

The eastern third of the cemetery is comprised of ordered rows of gravestones, dating from between 1928 and the early 1950s. These graves are highly standardized and arranged largely chronologically by date of death (Greenly 1996; Pippenger 1992b). The western two-thirds consists of irregularly-spaced stone markers. These gravestones are more variable in style, age, and configuration. When last surveyed, between 600 and 700 markers were present. Internment records suggest close to two thousand people are buried in Douglass Memorial cemetery (Natanson 2019).

The Common Council of Alexandria established Penny Hill Cemetery (44AX0134) in 1795 for use as a general burying ground (Miller 1987a, c; Figure 3). The cemetery was active until 1976 (Greenly 1996). This municipal burying ground is located on the 700 block of S. Payne Street between Franklin and Jefferson Streets, extended, and measures approximately 403 feet long by 290 feet wide. The cemetery sits in the southeastern section of the Wilkes Street cemetery complex. A portion of the southwest corner of the cemetery was deeded to Agudas Achim Congregation, the northern strip was deeded to Home of Peace Cemetery Association, and the remaining property consists of 2.26 acres of manicured grass maintained by the City of Alexandria (Pippenger 1992a). According to the parcel boundaries as depicted in the City of Alexandria Parcel Viewer, a strip of land approximately 20 feet wide extends beyond the eastern parcel line into the S. Payne Street right of way. When last surveyed (Greenly 1996; Pippenger 1992b), only eleven grave markers were present, and some of those were broken or otherwise damaged.

Penny Hill was in use for approximately 180 years, and historic documentation exists for at least 906 burials from the 20th century. Little is known about who is buried in this cemetery (Greenly 1996; Miller 1987c), though the interred may include both Black and white Alexandrians.



## 3.0 TECHNICAL BACKGROUND

### 3.1 Ground Penetrating Radar (GPR)

Ground penetrating radar (GPR) has evolved over the past two decades into one of the most commonly applied techniques for imaging the shallow subsurface. The method offers the highest resolution of geophysical techniques commercially available today. In many cases, the time required for the acquisition of GPR profiles is minimal, and subsurface profiles can normally be obtained in real time, making this tool very cost-effective. GPR works best in non-conductive soils, such as dry sand or sand saturated with fresh water.

The typical result of a GPR survey is a profile that presents radar wave amplitude as a function of distance along the line and two-way travel time. To know the depth to a reflector, it is necessary to know the average propagation velocity from the ground surface. The velocity of a radar pulse in an earth material is dependent on the relative dielectric constant ( $\epsilon_r$ ) of the material according to the following relationship:

$$V = c/(\epsilon_r)^{1/2}$$

where:

$V$  = velocity in a propagating material

$c$  = speed of light ( $\sim 3 \times 10^8$  m/sec)

This velocity can sometimes be estimated by knowing the characteristics of the propagation medium and, when the medium is air, the GPR technique can



*Surveying with X3M System at Douglass Memorial Cemetery*

accurately measure the speed of light. Propagation in soil is made through an analysis of the reflection patterns (moveout calculation) of the reflected signal. At both cemetery sites, this analysis derived an average velocity of 0.09 meters/nanosecond, which is a common velocity for soil. This velocity was used for estimating depths.

The soil conditions within the area covered by this investigation were favorable for good GPR penetration, and the GPR method was able to investigate to depths in excess of 6 - 8 feet.

### 3.2 Soil Conductivity Measurements

The electromagnetic (EM) conductivity method is a geophysical technique that measures the electrical conductivity of the ground, recorded as milli-Siemens per meter (mS/m). Variations in ground conductivity are due to both natural and cultural causes. Natural variations in conductivity may be caused by changes in soil moisture content, type of soil, depth of bedrock, and specific conductance of groundwater. Soil properties are affected by cultural activities.



*Data collection with the EM38 at Penny Hill Cemetery*

Fill in a grave shaft is usually an average of the physical properties of the surrounding, intact soil horizons, which means that, if there are vertical soil changes, the fill will probably have some physical contrast with the natural ground. Based on previous experience, our assumption at the start of this investigation was that grave fill is often of a lower density, higher porosity, and higher moisture content than natural soil, and can be detected as a conductivity high (resistivity low), primarily because of the higher moisture content. Our experience from this investigation shows that the opposite can also be the case. Other cultural features, especially buried metal, also affect the measured conductivity of the ground.

The EM conductivity method with an EM-38 uses a portable coil of wire to

transmit an alternating electromagnetic field (the primary field). The transmitted electromagnetic field induces electrical eddy currents to flow in the ground. These eddy currents produce secondary electromagnetic fields that are measured by a receiving coil. The secondary field is divided into components that are in-phase or out-of-phase with the primary field. The ground conductivity is calculated from the out-of-phase (quadrature) component. The in-phase value is related to the magnetic susceptibility of the ground and is especially sensitive to the presence of metal, although the quadrature phase readings are also influenced by metal. The instrument, in rare cases, can be adversely influenced by external EM fields, which proved to be the case at the Penny Hill Cemetery, located adjacent to the electrical substation south of Jefferson Street.

A limitation of the EM-38 is that it is not possible to simultaneously measure both conductivity and in-phase response when the equipment is deployed for rapid data gathering. Accordingly, to obtain the maximum possible surface coverage, only conductivity data were gathered with this survey.

### 3.3 Geomorphic/Geologic Background

Based on the geologic mapping of the City of Alexandria published by Fleming (2015), the two cemeteries are located on a late Pleistocene terrace of the Potomac River referred to as the Old Town Terrace (Figure 4). Douglass Memorial Cemetery is mapped to be completely over medium-coarse sand and gravel (Unit Qto on Figure 4), whereas Penny Hill is located in an area transitioning between stratified silt and clay (Qto-c on Figure 4) and the sand and gravel. Where soils could be observed in the field at both cemeteries, the main soils appeared to be sandy silt or silty sand, and the variability in the quality of the GPR signal indicated that some areas have more clay than other places across both cemeteries.

The apparent soil variability did not interfere with the interpretation of graves. Boulders that could complicate the interpretation of GPR are mapped in upland terrace deposits by Fleming (2015) but are not anticipated to be part of the Old Town Terrace. Coarse gravel, which could also impact the GPR interpretation, is associated with the Qto unit that is mapped west of the cemeteries, but the available data and field observations do not suggest that gravel interfered with the interpretation.

## 4.0 FIELD PROCEDURES AND DATA PROCESSING

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The Douglass Memorial Cemetery survey was conducted over four days, October 15 - 18, 2019. The Penny Hill Cemetery was surveyed from October 19 - 23, 2019. The fieldwork was affected by heavy rain resulting in two days when fieldwork could not be undertaken, the first on the 16<sup>th</sup> when over an inch of rain accompanied by high wind took place, and the 20<sup>th</sup> when Alexandria was affected by the remnants of Tropical Storm Nestor.

The first step in each survey was to assign a site-specific grid that was tied to Google satellite imagery (imagery from April 30, 2018) and this grid was tied into VA State Plane for incorporation into GIS. The grid for the Douglass Memorial Cemetery is shown in Figure 2 for the Douglass Memorial Cemetery, and Figure 3 shows the grid for the Penny Hill Cemetery. As graves can be expected to generally trend E – W, all geophysical survey lines were surveyed as N – S trending lines in order to best identify suspected grave features.

At Douglass Memorial Cemetery, the site grid is defined as 0 ft E – 0 ft N at a point on the inner curb of Wilkes Street, 3 feet east along the curb from where the iron fence forming the western border of the cemetery projects to the curb. Site E – W is taken to be the inner curb of Wilkes Street. The N – S trending geophysical lines were obtained progressing from W to E.

At Penny Hill Cemetery the surveying was also undertaken on the basis of N-S trending lines parallel to South Payne Street, but the progression was from E to W. The origin of the site grid is the inner edge of the curb along South Payne Street, opposite the utility pole in the SE corner of the survey area where the pole is located at 0 ft N – 6.5 ft W on the site grid, and the N- S axis is the South Payne Street curb.

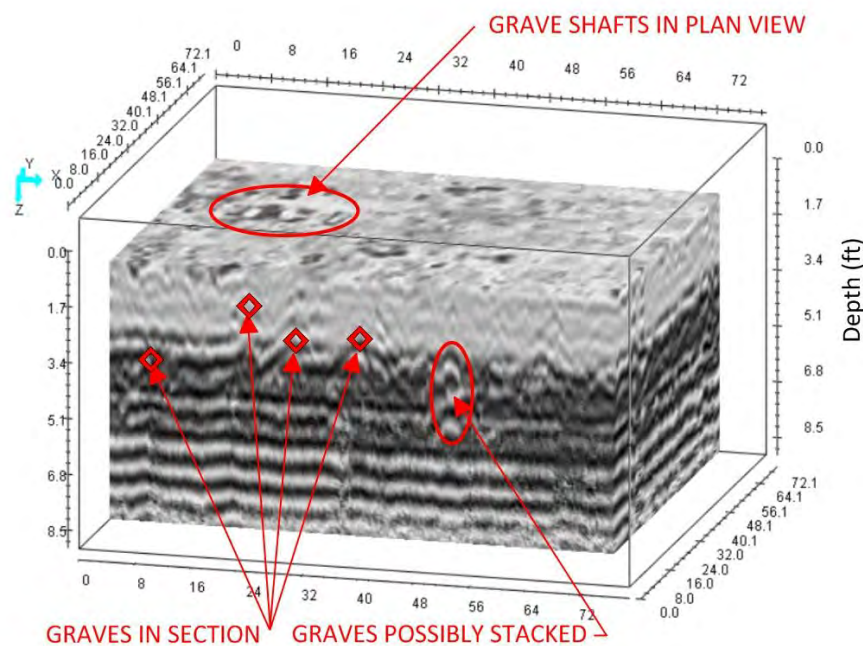
### 4.1 GPR Surveying

GPR surveying was undertaken on N-S trending profiles separated by 1.5 feet. Where the shape of an individual survey area permitted fixed start and end points, the survey was conducted by running the lines in two directions. Where obstructions such as large trees prevented two-way surveying, the survey was conducted on a unidirectional basis such that the ground surrounding the obstruction could be covered. Accordingly, the survey was conducted in individual blocks, shown respectively for Douglass Memorial Cemetery and Penny Hill Cemetery on Figures 2 and 3.



The GPR survey at Douglass Memorial Cemetery encompassed about 6.4 line-miles of data acquisition. The Penny Hill survey covered slightly more than 8 line-miles. During the survey, it was possible to visually observe on the instrument screen when a grave was traversed but defining the location of the burial and evaluating its characteristics were only possible with the 3D data processing.

The GPR data were processed with the Malå software program Easy3D such that interpretation could be made based on visualizing the data both in terms of individual GPR profiles, as well as three-dimensional blocks. Data viewed as a horizontal surface depict the variations in amplitude of the reflected radar waves corresponding to a specific reflection time and are referred to as “time slices”. Each time slice corresponds to a specific depth in the soil.



*3D block from Penny Hill Cemetery from depth of about 1.5 feet*

Interpretation involves identifying the hyperbolic shapes of the reflections from subsurface features and then viewing the reflections in plan-view to identify those that have the size comparable to a grave shaft (~3 ft x ~6 ft). Infant graves are obviously on a smaller scale than adult graves and tend to be shallower burials than those of adults. Infant burials are also more likely to be unmarked than those of adults, and some cemeteries have sections reserved

for infant burials that are not marked. Due to their small size, it can be difficult to map infant burials, and other buried objects like buried rocks can appear to be similar.

## 4.2 EM-38 Survey

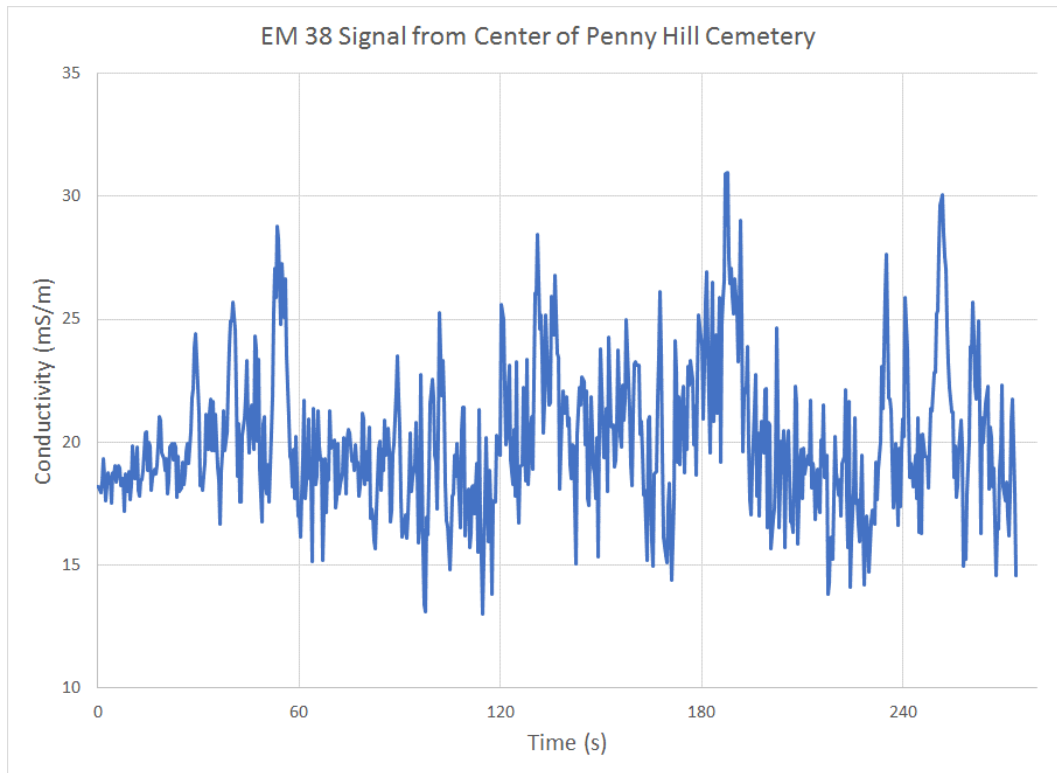
The EM-38 survey at Douglass Memorial Cemetery was conducted in profiles separated by 1.5 feet over the same lines that were followed by the GPR. For the EM-38, however, all the lines ran in one direction (about 6.4 miles of line). Close to 38,000 measurement points were collected. The measurements were made every 0.4 seconds, so it was necessary to assign distances along the line for each data point. For each line, the number of measurements was equally divided over the distance walked to obtain the position of each measurement along the line. The results confirmed that it was possible to maintain a constant walking pace such that nearly all measurements were spaced between about 0.8 and 1.0 feet apart along each profile.

The Excel file with the positioned measurements was then read into the Surfer 16 program for contouring. The data did not require additional processing, except to assign a color code to representative intervals, which are given in units of conductivity (mS/m – milli-Siemens/meter). The absolute values of the results are not considered critical, as it is the pattern of variation that forms the basis for interpretation. The EM-38 data were processed by downloading the measurements from the Polycorder recording unit to a PC. The data were then sorted into an .xyz file using Microsoft Excel.

A final step in the processing was to level the measurements between blocks to a common baseline. The EM-38 instrument drifts (changes baseline with time) due to temperature changes over the course of the day, so it is necessary to realign the values to a common base. The instrument drift is apparent when a common point is measured at two different times, as is the case where two blocks connect with each other. An E - W survey profile was also taken at the places where the blocks connected to verify that results were consistent. Readings were consistent, but it was necessary to make some drift corrections to the data.

An unexpected problem with the EM-38 proved to be the proximity of the electrical substation near the Penny Hill Cemetery. The substation caused interference with the readings from Penny Hill, easily observed by allowing the instrument to sit at a single location and observing the change in the

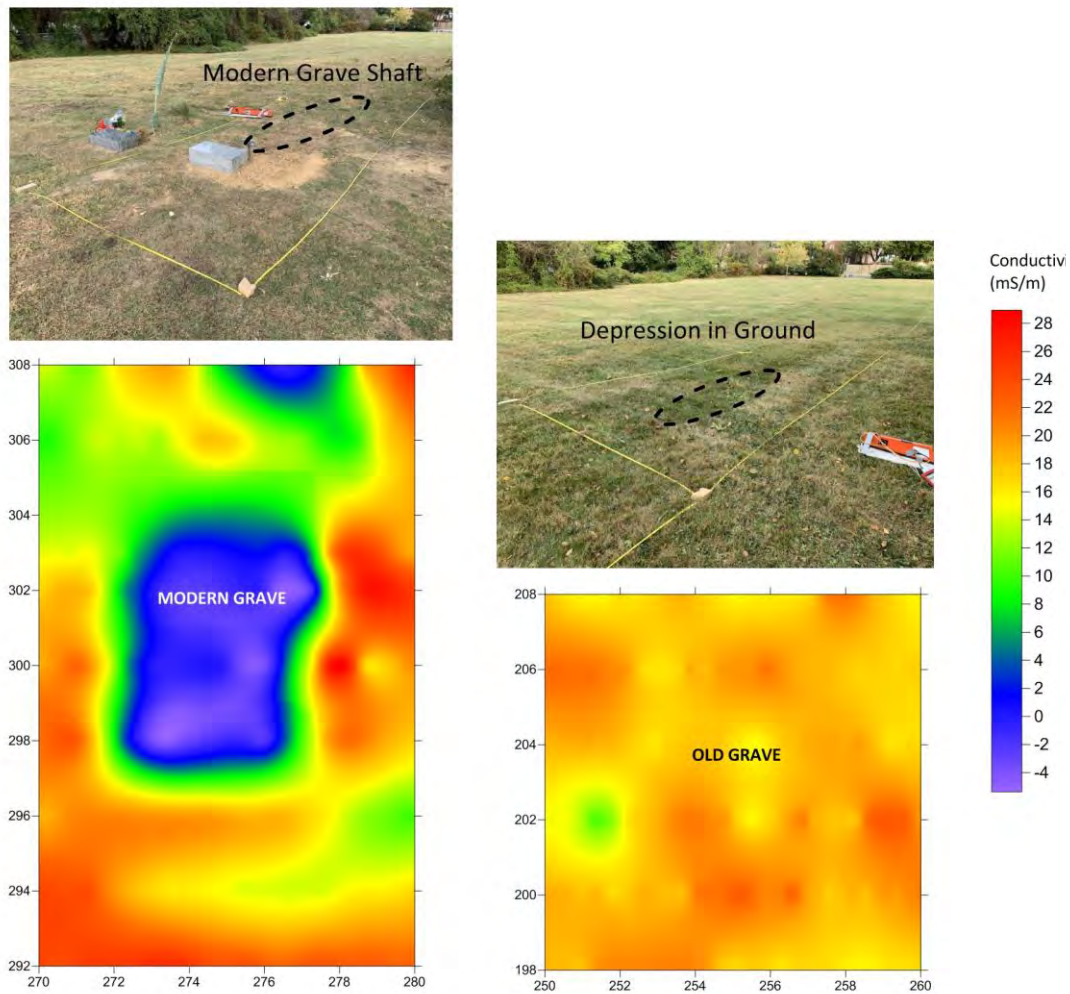
instrument reading. As shown in the following graph, the signal varied from about 14 mS/m to 31 mS/m over about a five-minute period.



*Erratic EM-38 signal from Penny Hill Cemetery*

Geophysicists interpret data in the context of the “signal to noise ratio.” The presence of “noisy” data does not necessarily mean that the survey will not be effective if the target of interest has a “signal” greater than the noise. In the case of this survey, the “signal” is the contrast of conductivity across a grave shaft. An experiment was conducted to attempt to image a modern grave and an old grave at the Penny Hill Cemetery using the EM-38. Although the measurements were erratic, a modern grave shaft could be easily imaged. An old grave shaft could not be imaged.

A surprising result of these experiments was that the modern grave shaft could be characterized by a low conductivity anomaly. Our previous experience with electrical measurements (see Johnson et al. 2015) is that grave shafts have higher conductivities than surrounding natural soils. As this modern grave shaft had a conductivity low over the shaft, we must assume that the soil is well-drained compared to the adjacent natural soil and has a relatively low moisture content.



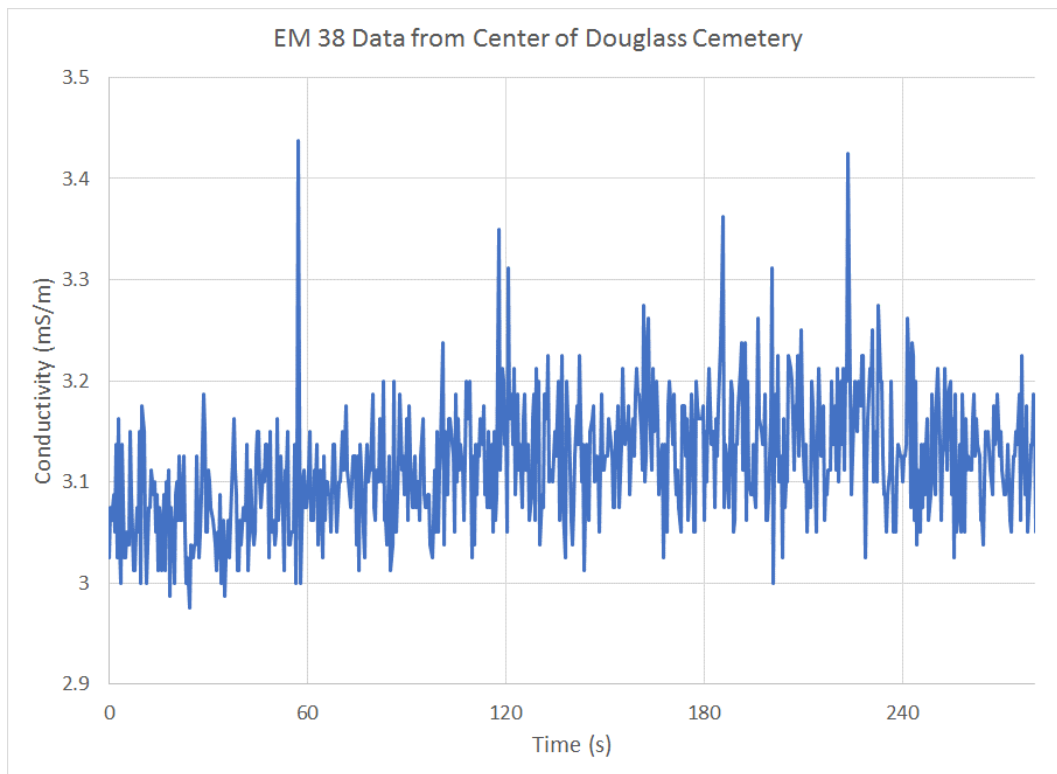
*Experiments to image a modern and an old grave with the EM-38 at Penny Hill Cemetery*

Old graves at Penny Hill Cemetery did not have sufficient physical contrast (or “signal”) to allow for their imaging with the high level of “noise” generated by the electric substation’s interference. For that reason, the EM-38 survey was discontinued after two blocks were surveyed in the SE and NW corners of the cemetery. The data were not interpretable.

The problems at the Penny Hill Cemetery led us to reevaluate the EM-38 data obtained at Douglass Memorial Cemetery.



A fixed point at the Douglass Memorial Cemetery was surveyed with the results as shown above. Noise from the substation is still present, but the data variation is typically plus or minus a tenth of a mS/m unit reading, not plus or minus more than 5 units. Accordingly, the EM-38 results at the Douglass Memorial Cemetery are considered to be representative of conditions in the ground



*EM-38 signal from Douglass Memorial Cemetery*

## 5.0 INTERPRETATION AND RESULTS

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### 5.1 Douglass Memorial Cemetery

Douglas Cemetery was surveyed with both the EM-38 and GPR. In terms of locating graves, the GPR was effective, but the EM-38 results of ground conductivity also offer information significant to the interpretation. The results of these two techniques are discussed separately.

#### 5.1.1 EM-38 Results

Figure 5 shows the results of the ground conductivity survey at Douglas cemetery where all values are presented in the display. The highest and lowest values relate to the presence of metal in the ground. The strongest anomaly is a metal pipe that is manifested by a negative anomaly, flanked by positive anomalies, that runs down the center of the sidewalk along Wilkes Street. An old pathway/road passing through the cemetery, centered at 190 ft E and perpendicular to Wilkes Street, is also well represented. There is a metal storm drain at approximately 190 ft E at the edge of the sidewalk where the pathway intersects with Wilkes Street that interferes with the instrument. The storm drain does not appear to be connected to any metal pipe that might follow the pathway, but it is possible that a non-metallic pipe is present. It appears more likely that the storm drain connects with a pipe beneath the sidewalk.

Within the cemetery, the highs and lows also relate to metal, assumed to be metal associated with burials. The strong negative anomaly at 105 ft E – 100 ft N is part of the reinforced concrete present as an enclosure surrounding a group of graves.

Figure 6 depicts ground conductivity values between 5 and 25 mS/m, typical values for soil. Much of the display shows extensive interference from metal, but the areas not obviously affected by metal still show significant local variations of soil conductivity. The image of ground conductivity in the 5 to 25 mS/m range is also shown on Chart 1 where the graves mapped from the GPR results are also shown. A correlation of ground conductivity with burials is not obvious. Our best interpretation is that the ground conductivity values represent natural changes in soil condition modified by the extensive digging of graves across the site.

### 5.1.2 GPR Results

Chart 1 shows the graves interpreted to be present at Douglass Memorial Cemetery. ~780 graves are interpreted from the GPR results. This number is on the low side because infant graves can be easily missed and there are places where burials are so concentrated in one area that individual burials cannot be identified.

Four different grave classifications are included in Chart 1. The first of these, “probable vault or intact coffin” reflects the highest confidence category (marked in blue). These represent probable individual burials, with clearly defined boundaries, suggesting the presence of some intact subsurface structure. The second category, “well-defined grave(s)” (marked in green) represents clear anomalies with boundaries that are not as clearly defined as an extant vault or casket. In this category, many of the graves include stacked or intersecting anomalies, indicating that they may represent multiple individual burials within the same small area. The lowest confidence category is “probable grave(s)” (marked in yellow). Within this category, a subsurface anomaly was observed, but the extent and boundaries of the anomaly may be unclear. As in the previous category, these graves may reflect multiple superimposed or intersecting burials. The largest areas where there are so many weak reflections of dimensions consistent with graves that individual graves cannot be identified are identified separately. A fourth category is represented by well-defined or probable graves that have dimensions smaller than an adult’s grave and Chart 1 depicts two sizes of graves.

Well-defined graves (26 graves interpreted to be vaults or graves with caskets in good condition and an additional 66 graves that are readily visible from the GPR profiles) comprise only about 11% of the identified burials, and the ones interpreted to be vaults or intact coffins comprise only about 3%. This statistic is indicative of burials in a cemetery where few of the families of the interred had the financial resources for vaults or substantial coffins. Images from the top foot in many places indicate the presence of a grave shaft, but there are no reflections from anything within the grave, suggesting that the burials in such cases were just the bodies with no type of containment, or coffins exceptionally susceptible to decomposition (like a pine box). These situations are marked as a “probable grave,” even though subsurface reflections characteristic of a burial are not identified.

The GPR results exhibit some small liner features in the shallow subsurface that are not obviously related to graves (Chart 1) but are not readily interpretable. One of the questions posed by Alexandria Archaeology at the

beginning of the fieldwork was if it might be possible to identify pre-cemetery structures including buildings associated with a Civil War hospital within the cemetery. Another question was if it was possible to find a pipe passing through the cemetery from the storm drain. Although we do see some linear features that are not obviously grave-related, none are obviously related to buried building foundations. It might be possible to miss a non-metallic pipe passing beneath the pathway that extends perpendicular to Wilkes Street at 190 ft E as the GPR lines would be parallel to the pipe and the pathway itself would mask the interpretation. The one feature clearly defined from the GPR results is the pathway/road that bisects the cemetery, even where the pathway is not readily observed at the ground surface. The characteristics of the cemetery east and west of this pathway are different.

West of the pathway, graves are generally present where indicated by conventional headstones, but there are many graves not marked by headstones. Specifically, there are concentrations of graves at about 70 ft E – 80 ft N; 80 ft E – 40 ft N; 115 ft E – 15 ft N; 80 ft E – 130 ft N, among other locations that are not marked by headstones. The more pronounced graves, interpreted to be vaults or coffins, are also marked by metal anomalies, and the metal anomalies are nearly entirely at locations where burials have been identified, even if the identification of the burials is not perfectly well defined. The portion of the cemetery west of the pathway represents about two thirds of the area of the cemetery, but close to 90% of the well-defined graves are present in this area. The northeastern corner of this western area does not have many headstones and, apparently, this is an area where few burials are present.

East of the pathway, the gravestones are similar in appearance and organized in straight rows, as in a military cemetery. The headstones are organized chronologically with the oldest graves in the SW corner of the eastern area and the most recent in the NE corner. Graves generally correspond to the headstones in the first two rows of graves in the western part of the area, but the order deteriorates eastward where there is less correlation of the graves with the headstones. There is a concentrated group of 18 headstones approximately located at 250 ft E between 12 ft and 35 ft N where there are no obvious burials although there are metal anomalies in this area. There are several burials centered at 250 ft E – 50 ft N where there are few headstones.

## 5.2 Penny Hill Cemetery

Although interference from the nearby electric substation made it impracticable to conduct an EM-38 conductivity survey at this site, the ground-penetrating radar functioned well, and subsurface disturbances showed up clearly. Overall, Penny Hill contains a remarkably high density of graves across the whole site. Chart 2 shows the locations of graves interpreted to be present in Penny Hill Cemetery.

Three different grave classifications are included in Chart 2. The first of these, “probable vault or intact coffin” reflects the highest confidence category (marked in blue). These represent probable individual burials, with clearly defined boundaries, suggesting the presence of some intact subsurface structure. The second category, “well-defined grave” (marked in green) represents clear anomalies with boundaries that are not as clearly defined as an extant vault or casket. In this category, many of the graves include stacked or intersecting anomalies, indicating that they may represent multiple individual burials within the same small area. The lowest confidence category is “probable grave” (marked in yellow). Within this category, a subsurface anomaly was observed, but the extent and boundaries of the anomaly may be unclear. As in the previous category, these graves may reflect multiple superimposed or intersecting burials. The areas where the probable graves were so concentrated that individual burials could not be identified are designated separately on Chart 2. At the Penny Hill Cemetery no attempt was made to distinguish different burial sizes, as such differences could not be identified as readily as at Douglass Memorial Cemetery given the generally more complex subsurface conditions at Penny Hill.

Several interpretive challenges prevent an accurate count of burials at the site. Records indicate that the cemetery had been in use between 1795 and 1976, and the oldest of these burials may not appear as clearly in the radar data. Older graves, especially in the context of a potter’s field, likely did not include vaults or caskets, which would stand out more clearly. Over time, the grave shafts themselves may become less pronounced. At Penny Hill, the density of graves presents another challenge. In densely buried areas with a high degree of disturbance, newer graves may intersect or overlap with older ones, either as a part of an intentional double-burial or through unintentional cross-cutting. Areas of high disturbance, and presumably high grave density, are marked on Chart 2.

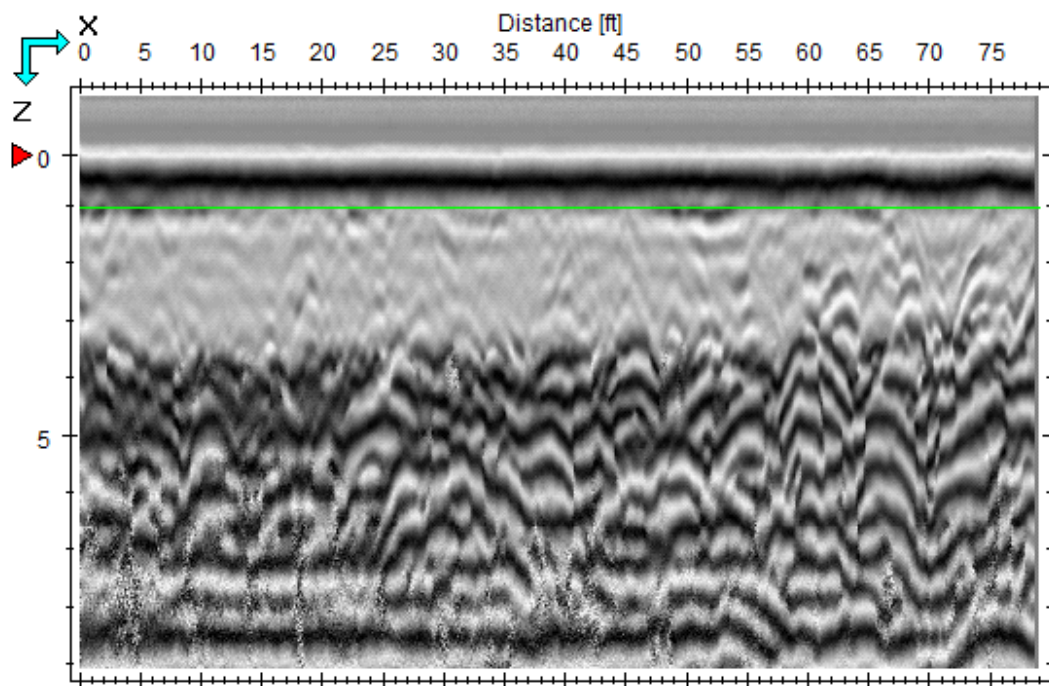
Much of Block 4 (identified in Figure 3) consisted of high-disturbance areas in which the identification of individual burials was impossible. The sample cross-section included below illustrates how closely grave-related anomalies intersect each other in these high-density areas. The anomalies are not uniform in depth, which may indicate that more recent burials were placed above, or intruded into, older ones.

The absence of identified anomalies on part of the chart does not necessarily imply the absence of graves in that area. Areas with no identified graves could still include burials without significant containment, such as the graves of infants or burials of cremated remains. Areas with natural soil disturbance could mask the presence of burials or, alternatively, cause misinterpretations that lead to the conclusion that graves are present when they are not.

Some soil changes are apparent at the site, particularly across Blocks 2 and 3. The distinct soils are visible on Chart 2 as large, dark blotches across the center of Block 2 and the western half of Block 3. These soil changes appear to be natural and not associated with grave disturbance.

Grave markers are almost entirely absent from Penny Hill Cemetery, so the graves at the site are generally not visible from the ground surface, except where grave-related depressions are apparent (as shown on Chart 2). At the time of the survey we were informed that there might be a well in the northern part of the survey area (best estimate at 348 ft N – 286 ft W) where tombstones had been dumped. Miller (1991) cites an anecdote from a nearby resident who said that he had seen many of the gravestones thrown down the well during his childhood, but the GPR results did not suggest the presence of a well in this area, nor was there a depression in the suspected area of the well that might define the well's location.

Records for Penny Hill Cemetery indicate that 906 burials took place at the site during the 20<sup>th</sup> century and, presumably, a significant number more took place in the preceding century. Excluding unidentified graves in high-density areas, 1,889 graves are conservatively estimated to be present in the cemetery. Of these, less than 1% (12 graves) are associated with a clear vault or coffin, and only ~9% (166 graves) fall into the second category of “visible grave(s)”. Graves in these higher-confidence categories are more common in the southern half of the cemetery.



*Sample cross-section of high-density area, from Block 4, 95 ft west. Each hyperbola represents a sub-surface feature (probable grave), from which the radar was reflected. Depth is given in feet.*

It should be noted that these estimates do not account for the reality that many of these anomalies may reflect multiple burials. Multiple-burials may be grouped too closely together to distinguish between them, or they may be stacked directly on top of one another. The practice of burying two individuals within the same grave shaft was common historically and may be difficult to identify through geophysical techniques. This estimate does not account for the fact that infant burials may not have been visible in the GPR data.

When conservative estimates for the high-density areas are included, the cemetery contains at least 2,075 graves, again not accounting for the presence of overlapping or intersecting burials. These estimates represent the low-end of the range of possible grave counts for Penny Hill Cemetery. If many of the site's graves include multiple burials, then the true number of graves would be higher than our estimate, but it would be difficult to estimate how much higher.

## 5.3 Summary

Of the two techniques applied, only the GPR was effective in mapping graves. The conductivity measurements taken at Douglass Memorial Cemetery reflected the presence of extensive interference from buried metal, likely to be grave related, but not diagnostic as to the location of graves. Meaningful conductivity measurements could not be obtained at Penny Hill Cemetery due to the proximity of an electrical substation.

Both cemeteries have a dense concentration of graves. In the case of the Douglass Memorial Cemetery the estimated number (in excess of about 780) is below the estimated 2,000 burials, but more than can be interpreted from headstones. West of the pathway bisecting the cemetery, there is a generally good correlation of grave with the headstones, but there are many graves where headstones are not present. East of the pathway, the gravestones are similar in appearance and organized in straight rows, reminiscent of a military cemetery. Graves generally correspond to the headstones in the first two rows of graves in the western part of the area, but the order deteriorates eastward where there is less correlation of the graves with the headstones. Overall, there is less correlation of graves with headstones in the eastern half of the cemetery.

At Penny Hill Cemetery, there is a remarkable density of graves across the site. In some areas, the density is such that it is not practical to map individual graves and it is apparent that in some places graves were dug over top of one another. The cemetery contains at least 2,075 graves, not accounting for the presence of overlapping or intersecting burials. This estimate represents the low-end of the range of possible grave counts for Penny Hill Cemetery.

In both cemeteries, the number of well-defined graves is low (close to about 10% in both cemeteries). This statistic reflects that few of the families of the interred had the financial resources for vaults or substantial coffins. Because of the fact that so few of the graves could be readily interpreted from the GPR record, the overall interpretation required significant interpretive effort, more than would be associated with an affluent cemetery. Ground truthing would be the only definitive method to confirm the findings of this survey.



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